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A comparison of neustonic plastic and zooplankton at different depths near the southern California shore

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Abstract

Previous studies of neustonic debris have been limited to surface sampling. Here we conducted two trawl surveys, one before and one shortly after a rain event, in which debris and zooplankton density were measured at three depths in Santa Monica Bay, California. Surface samples were collected with a manta trawl, mid-depth samples with a bongo net and bottom samples with an epibenthic sled, all having 333 micron nets. Density of debris was greatest near the bottom, least in midwater. Debris density increased after the storm, particularly at the sampling site closest to shore, reflecting inputs from land-based runoff and resuspended matter. The mass of plastic collected exceeded that of zooplankton, though when the comparison was limited to plastic debris similar to the size of most zooplankton, zooplankton mass was three times that of debris.

Keywords: Southern California; Neuston; Plastics; Zooplankton; Debris; Pollution monitoring

1. Introduction

Most studies of marine debris have focused on large, visible material found on beaches, with only a few studies describing abundance of small material in the water column (Derraik, 2002). The earliest of these in the Pacific was Shaw and Mapes (1979) who found a high density of plastics near the surface. More recent studies have shown that the mass of neustonic plastic can be comparable to that of zooplankton in both the mid-Pacific gyre (Moore et al., 2001) and along the California coast (Moore et al., 2002).

Studies of neustonic debris have been limited so far to sampling of surface waters. While some birds feed on plankton near the surface and could potentially consume surface debris, most filter feeding occurs below the surface. Plastics make up a high percentage of neustonic debris and many plastics are positively buoyant. Therefore, studies limited to collection in surface waters have the potential to overestimate prevalence of debris in the water column.

Our study extends previous work by comparing the density of neustonic debris and zooplankton at several depths along the California coast. The study also addresses how distribution in the water column changes following a storm event, when higher wind conditions and urban runoff have the potential to enhance vertical mixing.

2. Materials and methods

Sampling was conducted at two Santa Monica Bay sites offshore from Ballona Creek, which drains downtown Los Angeles. The first site was located approximately 0.8 km offshore and the second about 4.5 km offshore. Sampling took place on March 21, 2001 following six weeks without rain, and on March 25, 2001, following a 20 mm rain event.

The sampling site closest to shore was 15 m deep and was sampled near the surface and at 5 m depth. The second site was 30 m deep and samples were collected at three depths: surface, 5 m and near the bottom. Surface samples were collected using a 0.9×0.15 m^2 rectangular opening manta trawl with a 3.5 m long, 333 micron net and a 30×10 cm^2 collecting bag. Mid-depth samples were collected using paired 61 cm diameter bongo nets

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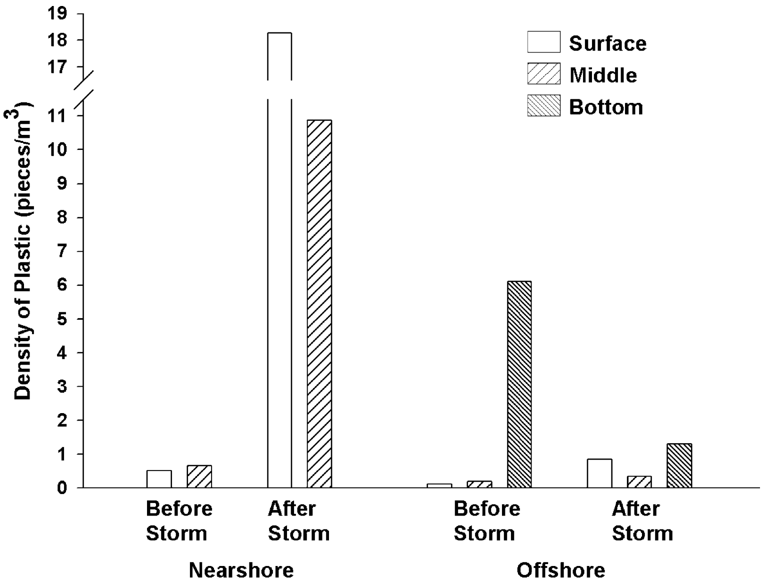

Fig. 1. Amount of plastic (pieces/m^3) before and after a storm at different depths and proximities to shore.

with 3 m long, 333 micron nets and 30×10 cm^2 collecting bags. Bottom samples were collected using a 31 cm^2 rectangular opening epibenthic sled with a 1 m long, 333 micron net and a 30×10 cm^2 collecting bag. The net on the epibenthic sample was located 20 cm from the bottom. Visual inspection by scuba divers showed sediment stirred from the bottom and did not enter the net. All samples were fixed in 5% formalin in the field, and later soaked in fresh water and transferred to 70% isopropyl alcohol.

Trawls were done parallel to shore for 10 min. Trawl speed varied between 1.0 to 2.3 m/s as measured with a B&G paddlewheel sensor, resulting in a trawl distance of between 0.5 and 1.0 km. A General Oceanics flowmeter was mounted across the net mouth during all deployments to measure the volume filtered.

In the laboratory, samples were placed in fresh water and floating plastic removed. A dissecting microscope was then used to remove remaining debris and plankton. Debris was sorted by category (plastics, tar, rust, paint chips, carbon fragments, and feathers) and plastics were further categorized (fragments, styrofoam, pellets, polypropylene/monofilament line, thin plastic films, and resin). Each category was sorted through Tyler sieves of 4.75, 2.80, 1.00, 0.71, 0.50 and 0.35 mm and counted. Plastics were oven dried at 65 °C for 1 h and plankton and plant material oven dried at 65 °C for 24 h, then weighed.

3. Results

Plastics were present throughout the water column on both sampling dates, but relative concentrations within the water column varied between dates and sites. The site closest to shore had nearly equal density at the two sampling depths before the storm (Fig. 1), but density on the surface was considerably higher after the storm.

Debris densities at surface and midwater depths of the offshore station were similar to that at the nearshore station; the increase in density after the storm was not nearly as large as at the inshore site. Debris density near bottom at the offshore station was considerably greater than at both the surface and midwater depths. Unlike surface samples, there was reduced debris density at bottom following the storm.

The spatial patterns for mass were similar to that of density, though the differences between dates were exaggerated (Fig. 2). For example, the weight of plastic increased by more than two hundred times on the surface after the storm. Much of this increase was attributable to the presence of larger items at surface after the storm (Table 1).

The average mass of plastic was 1.4 times that of plankton in this study, but much of the plastic mass was large material that is unlikely to be confused for planktonic prey (Table 2). When the comparison was limited to smaller particles (less than 4.75 mm), the mass of plankton was approximately three times that of plastics. This ratio was consistently higher near the surface and on the bottom than it was at mid-depth (Fig. 3).

4. Discussion

The plastic to plankton ratio that we observed near surface was similar to that found in previous studies (Table 2); ours was the first study, however, to measure it at other depths. While we found that there was more

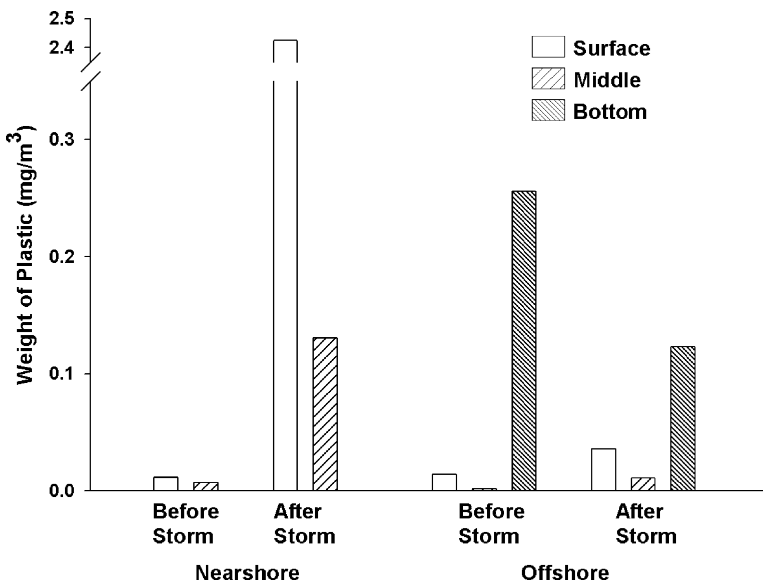

Fig. 2. Mass of plastic (mg/m^3) before and after a storm at different depths and proximities to shore.

Table 1
Percent weight and density of plastic by size and depth category

Size class	Category	Depth		
		Surface	Middle	Bottom
0.355–0.499	Weight	0.5	10.6	6.1
	Density	3.2	5.7	0.3
0.500–0.709	Weight	0.8	19.7	36.5
	Density	2.9	2.3	9.1
0.710–0.999	Weight	1.9	12.5	23.0
	Density	33.4	10.6	22.7
1.000–2.799	Weight	7.0	27.6	17.9
	Density	24.4	21.2	17.8
2.800–4.749	Weight	2.5	4.6	12.6
	Density	23.5	31.8	36.1
>4.750	Weight	87.2	25.0	3.9
	Density	12.6	28.4	14.0

Table 2
Comparison between this study, San Gabriel River study (Moore et al., 2002), and North Pacific Gyre study (Moore et al., 2001)

	Average debris		Ratio of plastic to plankton for mass	
	(g/m^3)	(pieces/m^3)	All debris	Debris <4.75 mm
This study	0.003	3.92	1.4:1	0.3:1
San Gabriel River study	0.002	7.25	2.5:1	0.6:1
Gyre study	0.034	2.23	6.1:1	0.3:1

debris near the surface than in midwater, we also found that there was more on the bottom than on the surface. When only small size classes were considered, there was little difference between surface and midwater densities.

It is commonly perceived that plastics are positively buoyant, but only 46% of manufactured plastics actually are (USEPA, 1992). Many buoyant items are products such as Styrofoam, in which air is injected. Even those plastics that are lighter than water at the time of manufacture can become negatively buoyant as they are fouled by biota or accumulate debris. We observed sand embedded in many items, such as plastic bags, that might otherwise float.

Few plastics are neutrally buoyant, which in the absence of turbulence would lead to a natural separation of debris top to bottom in the water column. The amount of turbulence necessary for resuspension of debris into midwater appears to be small. We observed that density near the bottom declined and midwater density was elevated after a storm, suggesting that storm or wind-related turbulence may be adequate for resuspension. This is consistent with the density of most plastics differing from that of seawater by a small amount (USEPA, 1992).

While mixing occurred in the shelf waters we sampled, the influence of resuspension in deeper waters is less clear. The distance from bottom to the middle of the water column is greater in deeper waters, meaning that more turbulent energy is required to resuspend bottom material to the middle of the water column and the influence of wind on mixing decreases with depth. Still, our study suggests that there is sufficient routine turbulence that potential biological effects of plastics in the water column are not limited to surface waters.

Many marine fauna are known to ingest debris (Fowler, 1987; Bjorndal et al., 1994; Robards et al., 1995; Blight and Burger, 1997), but few studies have

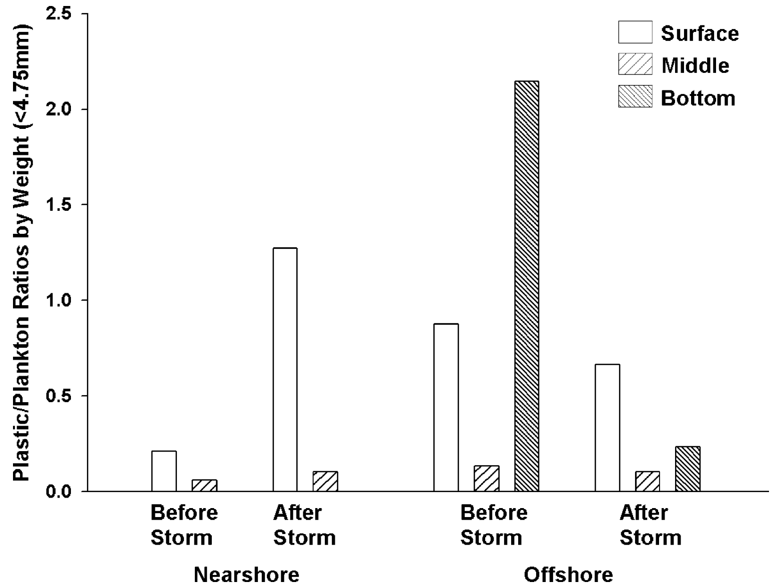

Fig. 3. Plastic/plankton ratios (pieces less than 4.75 mm) before and after a storm at different depths and proximities to shore.

examined whether they become artificially sated on this non-nutritive material (Ryan, 1987). Mato et al. (2001) found that contaminants adsorb to plastics, creating a potential for indirect effects of debris consumption; however, no study has considered whether this is a viable pathway for contaminant uptake by biota. These kinds of studies need to be conducted before we can fully assess the importance of debris in the water column.

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